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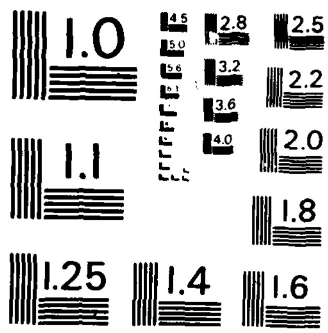
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EGLIN RANGE SAFETY COLOR GRAPHICS DISPLAY UNIT EVALUATION

Prepared For:

Armament Division (AD)
Directorate of Range Safety (SER)
Eglin Air Force Base
Florida 32542

Contract No. FO8635-79-C-0140
Study Task Order SER 82-2

23 APRIL 1982

Tybrin Corporation
2018-D Lewis Turner Blvd.
Fort Walton Beach, Florida 32548

Engineering Report ER-TC-SER 82-2

Eglin Range Safety
Color Graphics Display
Unit Evaluation

30 April 1982

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FOREWORD

The work on this report was sponsored by the Directorate of Range Safety (SER) at the Armament Division under Contract No. F08635-79-C-0140 and is a deliverable item under Study Task Order SER 82-2. The work was monitored by Mr. Lonnie Owen and Mr. R. H. Thompson.

ABSTRACT

The implementation of color graphics display units and interactive input devices for Range Safety monitoring of weapons tests is discussed. Evaluations of color monitors and input devices produced by five manufacturers are presented. Large screen display systems are also evaluated.

1.0 INTRODUCTION

The Gulf Test Range complex currently supports three major types of military weapon test environments: air-to-air, air-to-ground, and electronic combat. While the Range complex provides sufficient support for a majority of the weapons now being evaluated, it cannot, in its current configuration, provide range safety support for advanced technology weapons, multiple target missions, or multiple, simultaneous test missions.

In May 1981, the Southeastern Test and Training Area (SETTA) Range Improvement Committee produced a <u>Plan for Gulf Range Update</u> (Reference 4) to outline the instrumentation and facilities that will be necessary to meet the requirements of future weapon testing and pilot training at the Armament Division. Specifically, the Range must be capable of supporting an air-to-air mission consisting of up to 6 drone targets, four shooters, and four in-flight missiles. Currently, the Range can support one drone target and two shooters.

The safe operation of a test or training mission is of prime importance to all users of the Gulf Test Range facilities. In order to provide a safe operational environment, missions are monitored by Range Safety personnel from cathode ray tube (CRT) display units, driven by an integrated network of computers which transmit information to, and receive data from, a host of range instrumentation via cable and microwave links. The display units convey visual information (e.g., destruct lines, impact debris patterns, weather profiles, target and weapon positions, etc.)

that enables the RDO/RSO to make rapid, knowledgeable decisions concerning the safety of the mission. The CRT's in current use are monochrome units.

The planned Gulf Test Range upgrade, in conjunction with the scenarios of future test missions, will at least double the amount of visual information currently displayed to the RSO. Personnel monitoring a multi-target mission from a monochrome display unit will be severely hampered in decisions which require discrimination of critical test components; thereby jeopardizing human lives, property, or success of the mission. The utilization of color display units will, to a large extent, alleviate this problem.

The replacement of monochrome displays with color display units presents a number of considerations which are not immediately obvious. There are, for example, two schools of technology governing the manufacture of color display units: raster scan and vector scan. Color raster scan units are relatively inexpensive ($7,000. to $8,000); color vector scan units cost from $24,000 to $32,000. In addition, some manufacturers of units of each type have concentrated their efforts on an integrated system of microprocessor-controlled color graphics displays, and do not sell a stand-alone color CRT unit. The cost of these systems is over $100,000.

There are other considerations:

- Will the units interface with the current and the planned computer configuration?
- Is the screen resolution sufficient for the screen size?

- Are the multiple color/multiple display capabilities efficient?
- What peripheral devices may be used for control or interactive input?
- What will be the effect on the existing software?

The purpose of Study Task 82-2 is to investigate, with regard to these considerations, the attributes of color display units produced by a number of manufacturers, and tc .:ine those units which most expediently meet AD real-time ran(.afety requirements.

Since the function of the Tektronix 4014-1 display units in the real-time range safety test monitoring environment is to provide a secondary target track system to serve as a back-up in the event of failure of the primary system; and since the computer program which generates the 4014 presentations does not include certain displays (e.g., debris patterns) in which color would prove beneficial, the ramifications of implementing color on the Tektronix displays are not included in this report. A brief discussion of the Tektronix 4054, two-color CRT, is, however, presented in Section 5.3.

Because some manufacturers are reluctant to quote firm prices on their products, and because a number of the products consist of a basic unit, which increases in price with add-on options, the figures given in this report are estimates only. The estimates are based upon verbal quotes, and, where available, upon 1981 price lists.

2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 Conclusions

There are two methods of implementing color display units for monitoring test missions from the Central Control Facility (CCF) at the Armament Division:

1. Replacing the existing Vector General Series 3 system with advanced technology graphics processors.
2. Continuing with the existing system and replacing or adding Vector General color display units.

Both methods are capable of supporting the planned SETTA range upgrade, and both will interface with the planned installation of VAX 11/780 computers at the CCF.

The effective use of the Universal Graphics Language Executive (UGLE) system in the tightly interlaced hardware-software structure of the CCF precludes the expedient implementation of color display monitors driven by graphics processors. The UGLE subroutine library contains the capabilities for all the functions performed by a graphics processor, including color, windowing, zooming, translation, rotation and others.

The cost of replacing the current Vector General Series 3 system, in terms of purchase price, software conversion, and down-time is excessive in view of the fact that a suitable alternative exists.

2.2 Recommendations

The choice to replace or supplement the existing Vector General monochrome display units with Vector General color cathode

ray tubes (CRT) offers several benefits:

- The color monitor is relatively simple to install, since the connector ports and other hardware interfaces are compatible with the existing Series 3 mainframe.
- The simplicity of installation reduces the amount of down-time of the system for real-time range safety support.
- Color implementation can be "grown into". A color display unit may replace one of the monochrome CRTs that is not essential to mission support, and used for software development. Other units may be installed as needed to fulfill the SETTA requirements.
- The capability to present symbolic figures on the screen is relatively inexpensive and simple to install.

The implementation of Vector General color display units on the current Vector General Series 3 system is therefore recommended as the most feasible means of meeting the requirements of future AD range testing.

Addition of interactive input devices such as a data tablet and joystick is also recommended, since these items can greatly enhance the pre-mission setup procedures and examination of a specific portion of the whole mission scenario. The Series 3 will accommodate both of these instruments, and, in conjunction with the appropriate coding, sustain the SETTA requirements of multiple missions or multiple targets.

The implementation of Read Only Memory (ROM) cards to present tiny representative pictures (e.g., airplanes, ships) on the screen is also recommended. The combination of color and shape in a crowded scenario will provide the RSO almost instantaneous recognition of the many components that will be involved in the planned SETTA mission requirements.

The addition of Vector General color display units, a data tablet, joysticks, ROM cards, hard copy units, and software enhancements will sustain all of the Range Safety display requirements outlined in the statement of work. Many graphics processors currently on the market are also capable of meeting these requirements, and therefore, the products of five recommended candidate manufacturers are discussed in Section 5.0.

In addition, the capabilities of three Large Screen (greater than 2 feet square) Display (LSD) systems are discussed. The General Electric product, because of its advanced technology, portability, and competitive price is recommended.

3.0 TASK OVERVIEW

3.1 Selection of Display Manufacturers

There are, today, approximately three hundred manufacturers of computer terminals. Some produce only monochrome screens, some color, some produce both. There are screens as small as 6 inches (diagonal) and as large as 23 inches (diagonal). Some have graphic capability, some, only alphanumeric.

The first step in study task 82-2 was to narrow the field of manufacturers from whom to solicit information concerning their product. This was done by selecting, from Computer Terminals Review (Reference 3), those companies that produced display units which met the following criteria:

a. The unit must have at least four-color capability.

b. The screen size must be larger than 19 inches (diagonal) and have a resolution of a minimum of 512 by 512 picture elements. (See Section 3.2.1)

c. The unit must be capable of producing graphic displays.

Based upon these requirements, twenty manufacturers were sent letters asking for specifications pertaining to their color display units. Of the twenty, four had moved and left no forwarding address, and one no longer produced color graphic display units. One company sent only desktop computer information and did not indicate that it produced display monitors separable from the computers.

The fourteen companies that provided specifications were divided into two groups: raster scan or vector display unit

manufacturers. Megatek, Sanders Associates, and Tektronix, Inc. produce units of both types.

3.2 Raster Scan, Vector Display Units

The user of a color display unit may notice two distinct differences between a raster scan and a vector scan display: the shape of alphanumeric characters, or a straight line drawn in some direction other than horizontal or vertical, and the number of available colors. An understanding of how the lines and colors of each system are created will be helpful in subsequent discussion concerning display types.

3.2.1 Raster Scan Picture Creation

A raster scan display is made up of tiny "blocks" formed from horizontal and vertical lines which are spaced some minute distance apart. Each block - a picture element, or "pixel" - is addressable as a unique entity from a computer memory location. Typically, a high resolution screen will contain at least a 512 by 512 matrix of pixels, which, on a 19 inch diagonal screen, is an element measuring approximately .66 mm on each side.

There are two significant items arising from the capability to address each pixel individually:

1. The entire pixel will be colored.
2. Each pixel may be assigned a color.

The condition that each pixel must be entirely colored has the effect of creating "staircase" line (Figure 3.2-A),

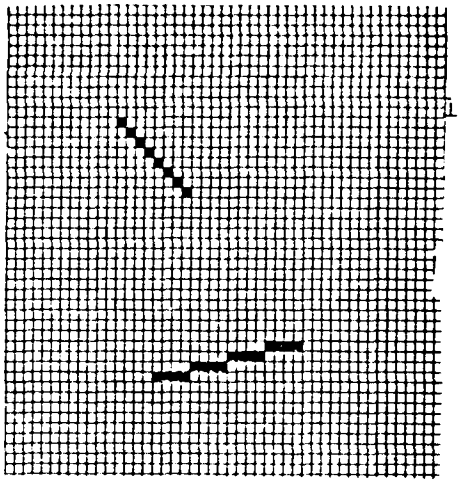

Figure 3.2A

Raster Scan Display

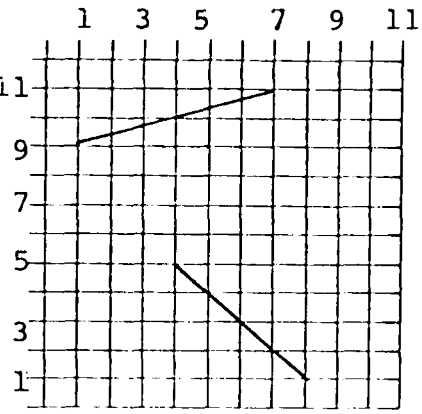

Figure 3.2B

Vector Display

although these become less noticeable as the screen size becomes smaller, and the resolution remains high. The ability to assign a color to each pixel permits the use of significantly more colors (a table look-up of 256 colors, in some systems) in raster display units than in vector units, most of which are limited to four colors. Individual pixel addressability also permits background coloring - a feature not possible in vector displays.

Raster scan displays form an image by directing an electron beam across the pixel rows of the whole screen in a regular left-to-right pattern. The picture is redrawn from 30 to 60 times per second to prevent image flicker, which results from decay of the phosphor beam.

3.2.2 Vector Picture Creation

A vector line is created by joining the x,y coordinates of one point with the x,y coordinates of a second point, using a phosphor beam approximately .381 mm in width (see Figure 3.2-B). The user of a vector display monitor does not observe the "staircase" seen in a raster scan display unit, and even though a curved line may be composed of many small vectors, the eye

perceives a smooth line. Vector displays refresh (excite the phosphor beam) the image at between 30 and 60 hz.

3.2.3 Raster Scan, Vector Display Manufacturers

The companies that responded to the request for product information are listed below.

Raster Scan Display Units	Vector Display Units
Advanced Electronic Design	Adage
Chromatics	Evans and Sutherland
Conrac	Megatek
Digital Equipment Corp.	Sanders Associates
Ferranti (LSD)	Vector General
General Electric (LSD)	
Intelligent System	
Megatek	
Ramtek	
Sanders Associates	Tektronix (Storage tube display)

An evaluation of the display units is presented in Section 5.0 of this report.

3.3 Real-Time Processing

In order to understand certain components discussed in the implementation of color display monitors, familiarity with both the current and planned real-time hardware/software configurations is necessary.

3.3.1 Hardware

The current and future hardware networks are shown in flow diagram form in Figures 3.3.1 and 3.3.2. The two most obvious differences are the replacement of the IBM 360/65 with VAX 11/780 machines, and the triple parallel PCL-11B bus interface which links the various components of the future network.

Figure 3.3.2 is somewhat misleading, since only four VAX 11/780 computers have been purchased. The additional two machines shown are included as part of a longer range plan (1984-1985), at which time the real-time processing currently performed by the CDC 6600 will be done on the VAX 11/780s.

Other elements, which are not shown in Figure 3.3.2, but which are of primary interest in implementing color display monitors, are the physical devices which link the CRTs to the PDP 11/35s or PDP 11/40s.

3.3.1.1 Vector General CRT Interface System

The current Vector General system in use at the CCF is the Vector General Series 3, Model 3D3I, depicted in Figure 3.3.3. The interface and controller combine to form a small (64 write, 128 read addressable registers) microprogrammed computer which receives digital input from the interactive control devices, or the PDP 11/35, and transmits the information to the CRT.

CCF REAL TIME CONFIGURATION

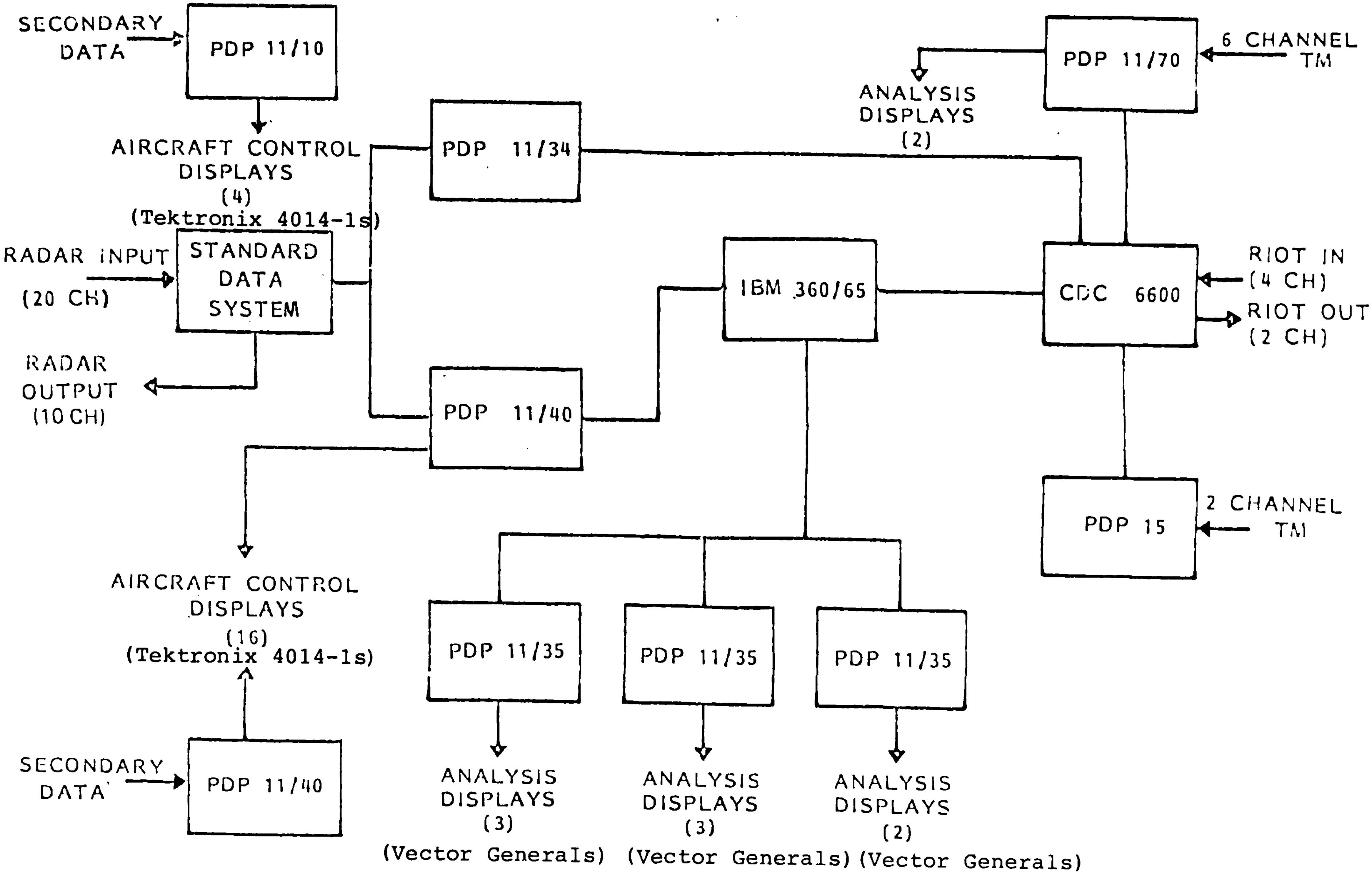

Figure 3.3.1

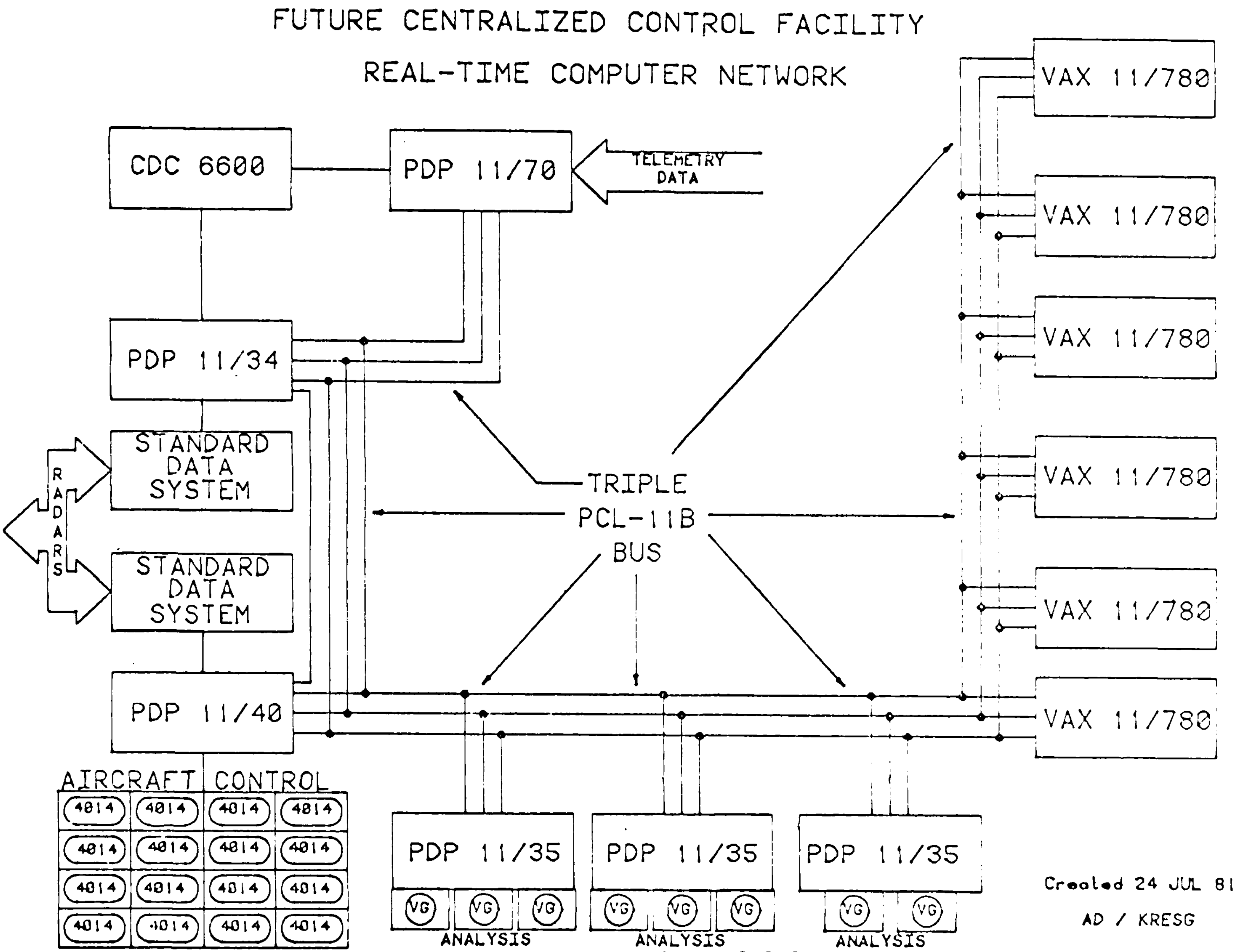
FUTURE CENTRALIZED CONTROL FACILITY
REAL-TIME COMPUTER NETWORK
CDC 6600
PDP 11/70
TELEMETRY DATA
PDP 11/34
STANDARD DATA SYSTEM
STANDARD DATA SYSTEM
RADARS
PDP 11/40
AIRCRAFT CONTROL
4014
TRIPLE PCL-11B BUS
VAX 11/780
VAX 11/780
VAX 11/780
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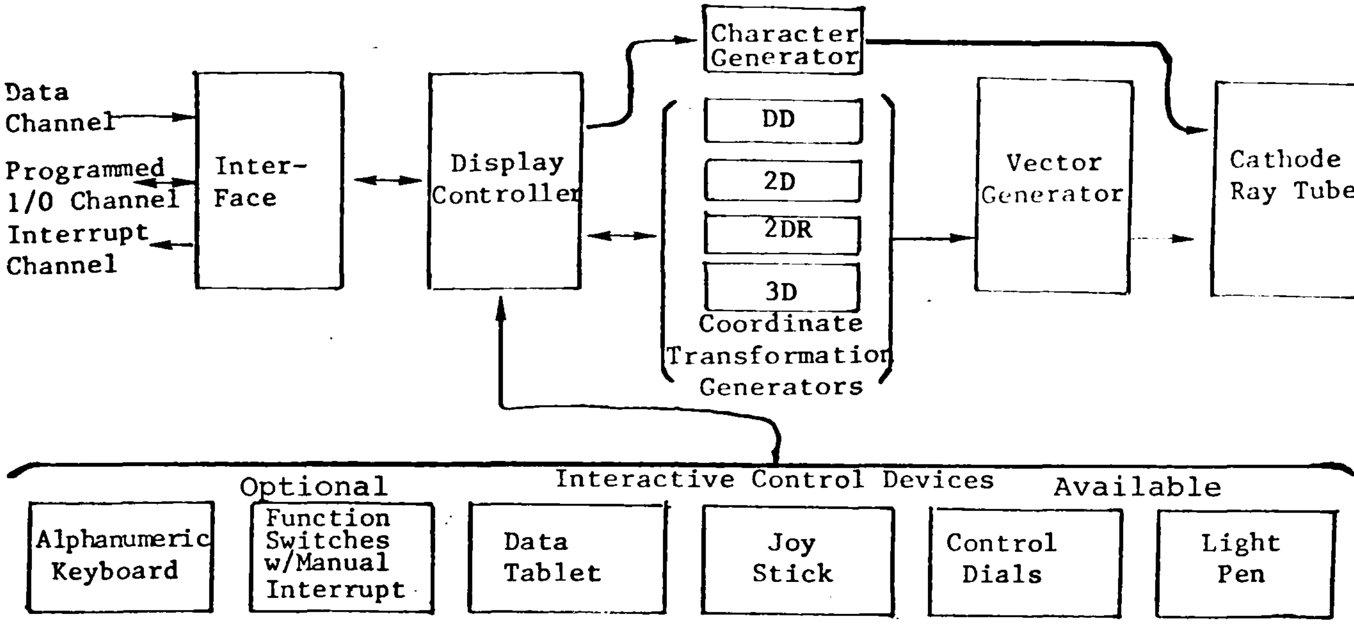
Figure 3.3.2

Each PDP 11/35 interfaces with one Series 3 system, which is capable of supporting up to four display units.



Vector General Series 3 Model 3D3I

Figure 3.3.3

3.3.2 Software

The current CCF software consists of a complex network of Fortran and machine language programs which reside on the CDC 6600 and IBM 360/65 computers, and which interface with the PDP 11/35 and PDP 11/40 computers to present graphics data on the associated display monitors. A detailed description of the software network and its integration of the CCF hardware is presented in Eglin Real-Time Computer Network (Reference 5).

The backbone of the display presentation procedure is the software of the Universal Graphics Language Executive (UGLE) graphics system. In this system, an UGLE job functions as a computer program executing on the IBM 360/65; however, its method of operation is somewhat different from the normal procedures used by a Fortran program.

Execution of an UGLE job is initiated by a subroutine call from P2457, which executes on the CDC 6600. Subsequent graphics subroutine calls from P2457 are sent directly into the UGLE buffers, at which time control is returned to P2457, while the UGLE job calls the corresponding Fortran library routines.

Calls to the routines add graphics data to the UGLE data buffers, which are converted to display code* for the various graphics devices, and sent out for screen presentation when the appropriate subroutine is called from P2457. Usually, clusters of three or more subroutines - the last being the screen initiator - are called successively, so that effectively, P2457 performs

*Machine language buffer converters are written for each device to convert the standard UGLE buffer data into the device specific display format.

calculations or defines parameters for screen presentation; quickly hands the data over to the UGLE job, and continues its processing path.

The UGLE system offers two advantages to the current CCF:

1. The transfer of subroutine calls into the UGLE buffers for a particular display presentation, then calling the graphics library routines from the buffers,accelerates the execution of P2457, since it allows almost uninterrupted flow through the coding. P2457 can continue its execution while the UGLE display job executes on the IBM 360/65.
2. Because the graphics decoding is done within the UGLE framework, the impact that display device replacement might have on modification of the real-time program (P2457) or other CCF programs is minimized.

The current plan of the Computer Technology Division of the AD for integration of the software into the proposed network of CDC 6600 and VAX 11/780 computers is, essentially, to retain the operating structure of the current software interface, and to implement the Fortran callable subroutines on the VAX 11/780s. Retention of the UGLE (GRXXX), the real-time system (RTXXX), and the telemetry (TMXXX) Fortran subroutines, and the concepts of their utilization, greatly minimizes the effort required for conversion of all real-time programs from one computer to another.

3.4 Interactive Input Devices

Users of remote alphanumeric terminals are familiar with a typewriter keyboard as a means of entering information into the computer memory. Graphics terminal users, however, have several choices of data entry devices. These devices include (in addition to a keyboard) light pens, control key panels, thumbwheels, trackballs, joysticks and data tablets.

Some of the devices are better suited to particular applications than others. For example, drawing a figure is relatively simple using a light pen or data tablet, but somewhat more difficult using thumbwheels or a trackball. Rotation and translation of a data base is generally performed by a joystick, while control keys are used primarily to bring a particular display from memory to the screen.

Data tablets, thumbwheels, and trackballs may be used very effectively for rapid input of data by presenting a menu (on the screen) to the operator, who uses the device to position a cursor (screen indicator) opposite the selection, and indicate the choice by depressing a key or button. The light pen may be used in the same manner, except that no cursor appears on the screen, and the indication is made by touching the pen on the screen at a specific point beside the item.

Implementation of input device capability requires both hardware and software interface between the device and the display unit to define the action to be applied to the screen presentation. The usual method employed is to utilize a library of subroutines which perform the graphic handling functions such as 2-D or 3-D

rotation of the figure, translation of the figure, windowing (selecting only a portion of the whole data base to be displayed on the full screen), zooming, line drawing, etc. Depending upon the picture processing system, the subroutines are activated by calls from the host computer application program, or the microprocessor program within the system. Initiation of the calls is based upon program interrupt (via a hardware signal) by an input device.

Another device, which is useful for inputting data by tracing lines from large hard copies (such as table-sized maps), is an intelligent digitizer. Large intelligent digitizers are not sold by the manufacturers of the display units considered in this report; however, one company, Summagraphics, was found to produce large digitizers in two sizes: 36" x 48", and 42" x 60". The digitizers are produced in opaque screens or in backlighted screens, and cost approximately $9500.00.

Summagraphics provides a full range of accessories and interfaces including 5 or 16 button cursors, or a magnifying cursor, and RS232, IEEE, and 8/16 Bit parallel. Resolution of the unit is .025 mm; accuracy is ± .125 mm.

4.0 DISPLAY UNIT IMPLEMENTATION

In the current, and proposed CCF configuration, there are basically two approaches to the implementation of color display monitors in the analysis consoles:

- Continuing with the current Vector General Series 3 system, (Figure 3.3.3) and replacing the monochrome CRTs with color CRTs, or
- Replacing the Series 3 system with a microprocessor graphics system (e.g., Figure 4.1) produced by Vector General, or another manufacturer, utilizing color CRTs in the system.

The points of consideration in the choice of approaches included not only cost (in terms of purchase price and software modification), but also the addition of features which will be necessary to support missions in the planned SETTA range upgrade. Some of these features are the use of icons (e.g., ship, aircraft outlines) for presentation of objects of concern; the use of flight-path-oriented predicted impact ellipses and debris triangles; the use of interactive input devices to draw figures (e.g., a ground hazard area) to be used during a mission, or, in conjunction with a menu, to select pre-defined items to be displayed, and a number of color monitors which will be necessary to support multiple targets or simultaneous missions.

These items, with regard to each of the two approaches to implementation of color display monitors, are discussed in the following subsections.

TYPICAL GRAPHICS PROCESSOR SYSTEM

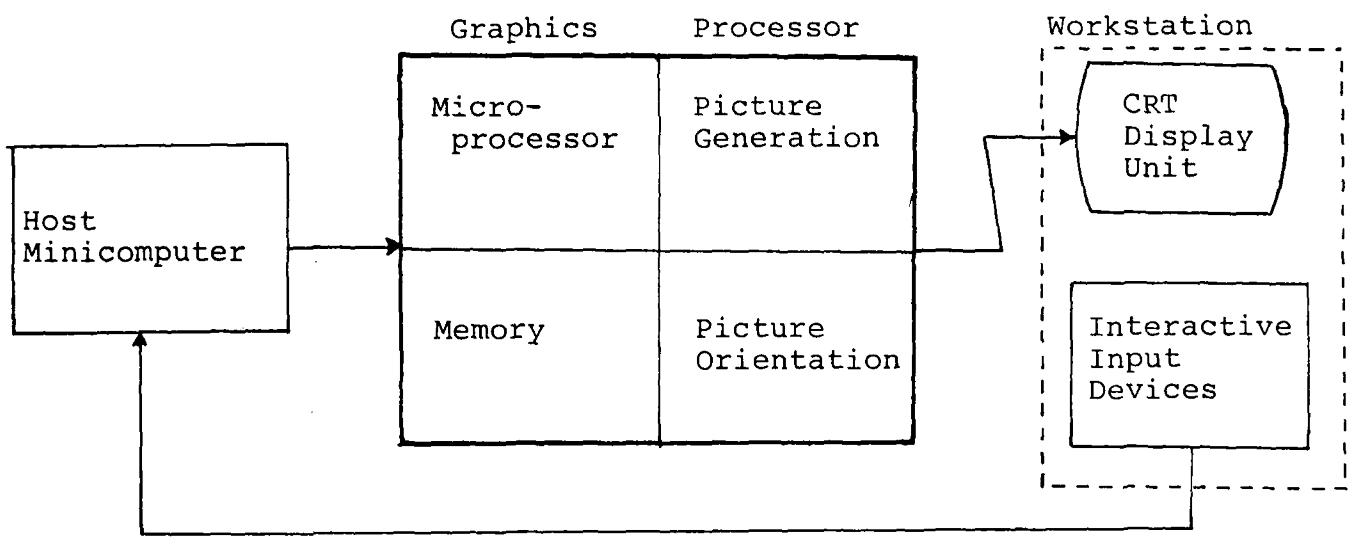


Figure 4.1

4.1 Color CRTs on the Series 3

The current Vector General Series 3 display unit connector ports will accommodate up to four, four-color, beam-penetration CRTs produced by CPS (a division of Vector General) with a minimal impact on the current software. The cost of each CRT is approximately $31,000.00.

In order to provide the capability of presentation of icons, Read-Only Memory (ROM) cards could be installed in the Series 3 system. The ROM cards would have been created by, and purchased from, Vector General at a cost of approximately $600.00 each, plus an initial fee of about $3,000.00. The installation of the cards could probably be accomplished best by CCF personnel who are familiar with the Series 3 system. Use of the ROM cards would require modification of program P2457 to request the specific figure(s) to be displayed, and to define positions and colors.

The capability of presenting flight-path oriented ellipses and debris triangles on the CRT would involve somewhat more extensive software revision. Calculations of the radii, focal point, orientation angle, and points to form the ellipse would be necessary, as would all the algorithms to construct the debris triangle. Additional calls to the existing UGLE subroutines would be necessary, but the current buffer converters are sufficient for drawing the figures by joining the end-points of many short vectors.

The interactive input devices available for the Series 3 consist of a keyboard, control key panel, light pen, data tablet, joystick, and trackball. The use of devices to select from a menu and for data input or the capability to draw a figure on the screen would require a substantial amount of revision of the current real-time program. These revisions would affect UGLE subroutines, both in calls from P2457 and in the buffer converters which reformat data into device-specific format for display. No additional UGLE graphic coding would be necessary, however, since the library currently contains rotation, transformation, zooming, and windowing subroutines.

The expansion to additional display monitors to satisfy the SETTA Range Upgrade could be accomplished by installing more CRTs on the existing Series 3 systems, attaching Series 3 systems ($48,500.00 each) to the existing PDP 11/35s, adding another PDP 11/35 and Series 3 system(s), or a combination of any of the methods. Past experience has shown, however, that optimum performance is obtained when no more than three CRT's are driven from one Series 3, operating on one PDP 11/35. Any expansion plans, therefore, should take this optimum mix into consideration.

4.2 Vector General Series 3 Replacement

The alternative to utilizing color display monitors on the Vector General Series 3 is replacement of the Series 3 with a graphic microprocessor system. Graphics processors vary in design and capability, but all systems have the common goals of (a) removing as much of the graphics processing load as possible from the host computer, and (b) minimizing the programming task. Most vendors accomplish both goals by providing Fortran callable subroutines which are compatible with the compiler of the specific host computer, and which address hardware functions within the graphics processor itself.

In both the current and proposed CCF networks, the host computer for a graphics processor would be the PDP 11/35. The real-time program, operating on the CDC 6600/IBM 360-65, the CDC 6600/VAX 11/780, or the VAX 11/780, would function primarily as a data generator for information to be displayed on the screen. The PDP 11/35s, in conjunction with the graphics processor, would handle the graphics format of the screen presentations by means of a separate applications program executing on the PDP 11/35.

There are several ramifications to implementing a graphics processor sytem in the Eglin CCF:

Purchase Price. Graphic processors which employ vector type color CRTs, and have 256K words of internal memory, are relatively expensive - from approximately $70,000.00 to $120,000.00 Raster scan color CRTs reduce the price by approximately $18,000.00 per CRT.

Software Considerations. As mentioned in Section 3.3.2, the purpose of the UGLE subroutine library is to reduce the impact on software modification of the Eglin real-time computer program, in the event of replacement of the Series 3 or 4014-1 systems. The use of the UGLE subroutines, however, places a portion of the burden of graphic display development on the real-time program, and in so doing, utilizes processing time that could be devoted to complex mathematical calculations.

Efficiency. There have been no comparative studies of the processing time required by the UGLE system for a given job vs the time required by a graphics processor for the same job. The actual processing efficiency gained by implementation of a graphics processor is therefore unknown. There are, however, two significant considerations:

1. If graphics processors are interfaced with only one or two of the PDP 11/35s, the UGLE subroutines must be retained in the real-time program to support the remaining Vector Generals and Tektronix 4014s. Retaining the UGLE subroutines for graphics capability on some Vector Generals while utilizing a graphics processor for other displays not only defeats the purpose of a graphics processor, but also constitutes additional pre-mission effort to bring up the applications program and run diagnostic checks on two or more systems.

2. If all Series 3 units are replaced with graphics processors, the current real-time program could be made more efficient by removing calls to all of the UGLE subroutines except those used by the 4014s. A significant amount of revision of P2457 would be required to remove the unnecessary UGLE calls, and to initiate action of the graphics processor.

The use of icons, impact ellipses, and debris triangles are also affected by these considerations, since the presentation of these figures on the screen is controlled by graphics software. If any Series 3 systems remain, the circumstances for implementing these features are the same as discussed in Section 4.1. If all Series 3 systems are replaced, these features would become functions of the graphics processor. Depending upon the graphics processor chose, the icons could be developed by programmers who maintain the real-time program, rather than the graphics processor manufacturer.

Additional display monitor units for support of simultaneous missions, or multiple target scenarios, could be implemented in much the same manner as discussed in Section 4.1. The optimum mix of CRTs, graphics processors, and PDP 11/35s will depend upon several factors, such as the type of graphics processor employed, the number and types of missions conducted, and the number of personnel required to monitor the missions.

5.0 Display Unit Evaluation

The products of seven manufacturers, from the fourteen respondents listed in Section 3.2.2, were selected for further evaluation with regard to integration into the Eglin real-time system. The remaining six were exluded due to (a) inability to interface with the PDP 11/35; (b) lack of a Fortran software package; or (c) incompatibility of the CRT with Series 3 display connector ports.

The seven companies selected for evaluation may be grouped as follows:

- Large Screen Displays: Ferranti, General Electric
- Graphic Display Systems: Adage, Inc., Evans and Sutherland, Megatek, Sanders Associates, Vector General

5.1 Large Screen Display (LSD)

Large screen graphics displays are generated by the projection of an image onto a screen, either from in front of the screen (similar to a movie camera) or from behind the screen toward the viewer. The quality of the image displayed depends primarily upon the design and construction of the projector guns, the reflective properties of the screen, and the manner in which the image is transmitted to the screen.

In order to utilize raster scan LSD's (G.E. or Ferranti) with vector-generated data from the Series 3, it is necessary to interface the display controller and the LSD with a scan converter. G.E. has successfully used scan converters produced by Princeton Electronics at a cost of approximately $7,500.00.

In addition to the two companies (G.E. and Ferranti) who provided written information concerning their product, Cubic Corporation provided verbal information and a demonstration of their large screen display at the ACMI facility at Eglin.

Because the G.E. product differs significantly from the other large screen display systems, it will be discussed first.

5.1.1 General Electric

The G.E. model PJ5050 television projector is a new approach to presenting large screen sealed light valve color displays. Previous light valve color projectors utilized three electron guns and three rasters (one raster for each of the three primary colors), or a two-gun, two raster system in which one raster was used for green, and the other for red and blue. In these systems, the color images resulting from the raster scans must be optically registered (mixed) at the screen to produce the colors of the spectrum.

The G.E. PJ5050 projector utilizes one electron gun and one raster, determining a color mix of the three primary colors from diffraction gratings within each pixel in the raster scan. The resulting image, in its proper color, is passed through a Schlieren-projection lens onto the screen; thereby obviating the need for registration of the three color images as was necessary in the multi-gun systems.

The end result of the G.E. approach is a product which offers several significant benefits to potential customers.

- The entire projector system is comparatively small and portable. Outside case dimensions are 17" width, 22" height, and 30" depth. It weighs 125 lbs. and may be mounted on a 4-roller stand.
- The picture size is variable from 2 feet wide up to 20 feet wide (as a function of the throw distance), and may be front or rear projected. Two adapters - a 1/2x and a 2x - are available to enhance the throw distance capabilities.
- The brightness of the picture is greater than most multi-gun systems. White picture output is typically 280 lumens.
- Resolution capability is approximately 600 TV lines.
- The system has less than 2% distortion using the standard project lines without an adapter.

The PJ5050 is employed in a wide variety of applications, TV weather reports, stock market trading averages, classroom presentations, and is therefore a commercially produced, off-the-shelf item. The retail price of a PJ5050 system is approximately $78,000.00, which does not include a screen.

5.1.2 Cubic Corporation

Cubic Corporation utilizes a two gun system for large screen displays. The color projector guns are large (each uncased, is roughly 12" in width and height and 24" to 30" in length), heavy (about 150 lbs. each), and highly dependent upon a low ambient temperature for proper operation.

The demonstration provided by Cubic Corporation at the ACMI Eglin facility indicated that several areas of performance needed improvement if a high-quality persentation is to be made. Observations of particular note are:

- The deterioration of line clarity from screen center to screen edges.
- A low contrast between lines and background screen.
- A blurring of the alphanumeric characters.

It is anticipated that newer model color guns will replace the existing system, and presumably some of the current deficiencies will be remedied. The newer systems cost approximately $140,000.00, including the screen.

The Cubic LSD's are used extensively at military installations throughout the U.S., particularly in a Tactical Aircrew Combat Training System (TACTS) environment.

5.1.3 Ferranti

Ferranti is an English company that specializes in the production of air defense display and communications systems. The Ferranti projection system uses three color guns, which are connected to one projector. Each color gun (red,green, blue) contains a small

($\approx$ 125mm) CRT upon which the computer-produced image is "painted", then electronically transmitted to the projector. The colors cannot be mixed at the projector to produce spectrum variation; however, distinct and different images from each gun may be projected simultaneously.

The use of a single projector for the three primary colors prevents registration at the screen (to obtain multiple colors) so Ferranti recommends using three of the three-gun units. In this way, the same image is projected from each of the three units, but from a different color gun in each unit. The like images are then registered at the screen to produce the desired color.

The three gun units require an operating space approximately 6' wide, 3.5' high, and 1.5' deep, and must be positioned at least 20' from the front of the screen. (Rear projection capability is not available.) The screen may be any white matte surface with a reflectance of .70 or better.

The retail price of a single tri-color system is 138,750 pounds sterling (approximately $77,000.00).

5.2 Graphics Display Systems

The graphics display systems evaluated, though different in construction, are, in essence, comprised of four modules: 1) a work station, consisting of a CRT and one or more input devices; 2) a graphics processing/memory buffer module; 3) a software package; and 4) a host computer.

Presentation of the screen picture is controlled by the software package provided by the display system manufacturer. The distribution of the elements of the software package between the work station, the processing/memory buffer module, and the host computer is the primary difference among the display systems, and is a major factor in controlling the time lag between input device request and screen display response.

Another major factor that greatly affects response time as well as the number of lines that may be drawn, is the number of work stations supported by one processor/memory buffer module. Most of the manufacturers indicate that the processing/memory buffer module of their display systems will support up to four work stations, but this advertisement is usually qualified by the statement that in certain applications, maximum operating efficiency is obtained with one work station per module.

Since one measure of the effectiveness of any equipment is its field-proven performance, those locations where the specific graphics processor is known to be operational have been included for reference.

5.2.1 Adage

The standard CRT featured for the Adage 4100 Series of graphics display systems is a 21 inch high-resolution monochrome unit, however, a similar, color unit is also available as an option. The color unit contains four colors, with no variation in hue. Up to three work stations may be connected to one processor unit.

Adage offers an optional feature which allows the user to define up to 128 symbols and characters to replace the standard character set. This option would provide the capability of presenting small icons on the screen to represent elements of a weapon test scenario. Other features of the screen presentation capabilities include solid, dotted, dashed, or dot-dash lines, and a 128:1 zoom ratio which effectively enlarges the working picture space to 512' by 512'.

The Adage software package consists of five parts:

- The Graphics Programming Language (GPL). The Adage GPL is a compiler which produces an object file from a Fortran IV applications program. The object file is loaded into the 4100 refresh memory, and may be executed from there, or in conjunction with a program executing on the host. Judicious programming optimizes the distribution of processing, and thereby minimizes display response delay.

- Graphics Peripheral Object Time System (GPOTS). The GPOTS is a set of Fortran IV callable subroutines, written in assembly language, which provide the host with display hardware control, graphic element construction, interrupt processing, and application program-GPL interface.
- Graphics Peripheral Device Handler. This module provides the software interface between the 4100 processor/memory buffer area and the host computer.
- Graphics Peripheral Console Handler (GCOM). The GCOM, used with the graphics peripheral device handler, allows the Adage CRT to be used as a remote terminal to the host computer.
- Display Text Editor. The text editor may be used with the GCOM and a host computer to edit program or data files in much the same manner as the CDC 6600 text editor.

The buffer memory of the 4100 series is expandable up to 128k bytes. This size is sufficiently large for almost any application program or data base.

Adage supports seven interactive input devices: alphanumeric keyboard, light pen, joystick, lighted function switches, trackball, variable control dials, and a data tablet which is available in six sizes from 11" x 11" to 36" x 48".

The Adage sales representative was reluctant to provide an itemized price list, therefore only ball-park estimates are given. His quotation for one 4145 graphics processor system, with color display unit, data tablet, joystick, function keys, and 64k of memory was "about $110,000."

The Adage system is currently operational at the White Sands Missile Range. When the system was observed (October 1981), problems existed in the implementation of the color CRT's, and therefore, only the performance of the monochrome display unit was witnessed. The system provided rapid response to commands, and the display was clear, with the exception of a slight ghost that followed a rapidly moving figure or line.

5.2.2 Evans and Sutherland

The Evans and Sutherland Multi-Picture System processor is available with monochrome or color display units, and will support up to four picture stations, each containing a color or monochrome display unit. The CRT has a 26" diagonal screen which can display a (programmable) selection of 64 hues with 7 color saturation values - or, a total of 448 colors. Evans and Sutherland was the only manufacturer (of vector generated displays) that advertised a CRT containing more than 4 color capability.

In order to obtain icon presentation capability, a data set of defined figures would have to be created, stored on disk, and read into the memory buffer prior to execution of the applications program. Creation of the figures would require development

of a special applications program designed for that specific purpose.

Lines presented on the screen may be dotted, solid, or dashed in long-long dashes, short-short dashes, long-short dashes, or dot-dashes, and may be any of the 448 colors. The Evans and Sutherland multi-picture system also has the capability of zooming up to a 128:1 ratio of presented data.

Evans and Sutherland has chosen to control its Multi Picture System with Digital Equipment Corporations VAX/VMS or PDP 11 series computers (only). The software interface, therefore, is written specifically for these machines, and has been designed for maximum operating efficiency. The graphics software operates from the processing/memory buffer area, and can support up to four picture stations. Each picture station may be programmed, and functions independently of any of the other picture stations which utilize the common central graphics processor. Picture station programs may be easily interchanged within the multi-picture system.

Each picture station may support one or more of the interactive input devices. Optional devices include: 1) a light pen; 2) alphanumeric keyboard; 3) control dials; 4) joystick; 5) lighted function buttons; 6) function switches; and 7) an 11" x 11" data tablet.

The picture processing/memory buffer area is expandable up to 256K 16-bit words (128K bytes).

The retail price of one multi picture system (excluding the DEC mini-computer) containing one picture station with one color CRT, 32K words, console work station, software, user documentation, and the necessary cables and interface busses is \$117,000. Prices of optional devices are as follows:

Data Tablet	\$4,950
Light Pen	\$4,950
Alphanumeric keyboard	\$2,675
Control Dials (8)	\$3,300
Joystick	\$3,800
Lighted function buttons (32)	\$4,900
Function switches	\$2,750

Evans and Sutherlands graphics processor systems are installed at the Western Test Range (WTR) facility at Vandenberg A.F.B., California, and at White Sands Missile Range in New Mexico. The system at WTR is used for Range Safety display purposes.

5.2.3 Megatek Corporation

Megatek has oriented its graphics processor system toward a single processing/memory buffer which simultaneously drives both a vector CRT and a raster scan CRT. Megatek's market is aimed at design engineering, which requires the fine detail of vector graphics (e.g. the lock on a car door) as well as large area evaluation; as another example, pixel fill of an area in various shades of color can be used to represent varying amounts of stress on a beam. Megatek has designed both hardware and software to support simultaneous operation of the two display units. The processing/memory

buffer (called the Graphics Engine by Megatek) will support up to four color displays, with interactive input devices for each, and is expandable to 128k bytes.

Both vector and raster scan display units have a 21" (diagonal) screen. The vector unit has four-color capability, while the raster unit supports up to 16 colors, chosen from a 4096 color palette.

Megatek, like Adage, offers a programmable read-only memory (PROM) option which provides up to 128 user defined symbols for icon presentation capability.

The software package (WAND 7200) provided by Megatek is written in ANSI Fortran, so that the system may be interfaced with almost any computer. The WAND 7200 package allows the user to write interactive graphics which, without modification, can be run on vector diaplays or raster displays. WAND 7200 also supports simultaneous vector and raster displays.

The WAND 7200 software package allows programs to be written at four levels within the graphics processor.

- System Level Routines. WAND 7200 system level routines contain device drives, routines for initialization, and routines for computer interface. These routines are not normally used by the applications programmer; however, entry points are provided so that a systems design programmer may write the most efficient code possible by avoiding functions not required for a particular application.

- Workstation Level Routines. The Fortran workstation routines control the display functions such as windowing, zooming, rotation, scaling, color control, etc.. Workstation level support is also provided for the interactive input devices, so that much of the graphics processing load may be removed from the host, or so that host independent programs may be developed.
- User Level Routines. The user level routines provide the capability for programmable control of a discrete data base: the portion of the whole to be viewed; the viewpoint, and view direction; and the coordinates in which the data base is to be displayed. The user level routines also determine which portion of the screen is to contain the image.
- Utility Level Routines. The utility level allows the user to construct his own software libraries to perform often-repeated functions. Routines programmed at this level, performing functions targeted to specific applications, make use of the Megatek graphics processor in the most effective manner.

The WAND 7200 programming levels are interconversant so that by prudent distribution of processing tasks within the levels, the system may be made to operate in the most efficient manner possible.

Megatek input devices consist of: alphanumeric keyboards, joystick, light pen, graphics tablet/digitizer, function switches, and control dials. Megatek offers the option of combined packaging, such a a joystick mounted on the alphanumeric keyboard, or one panel containing function switches and control dials.

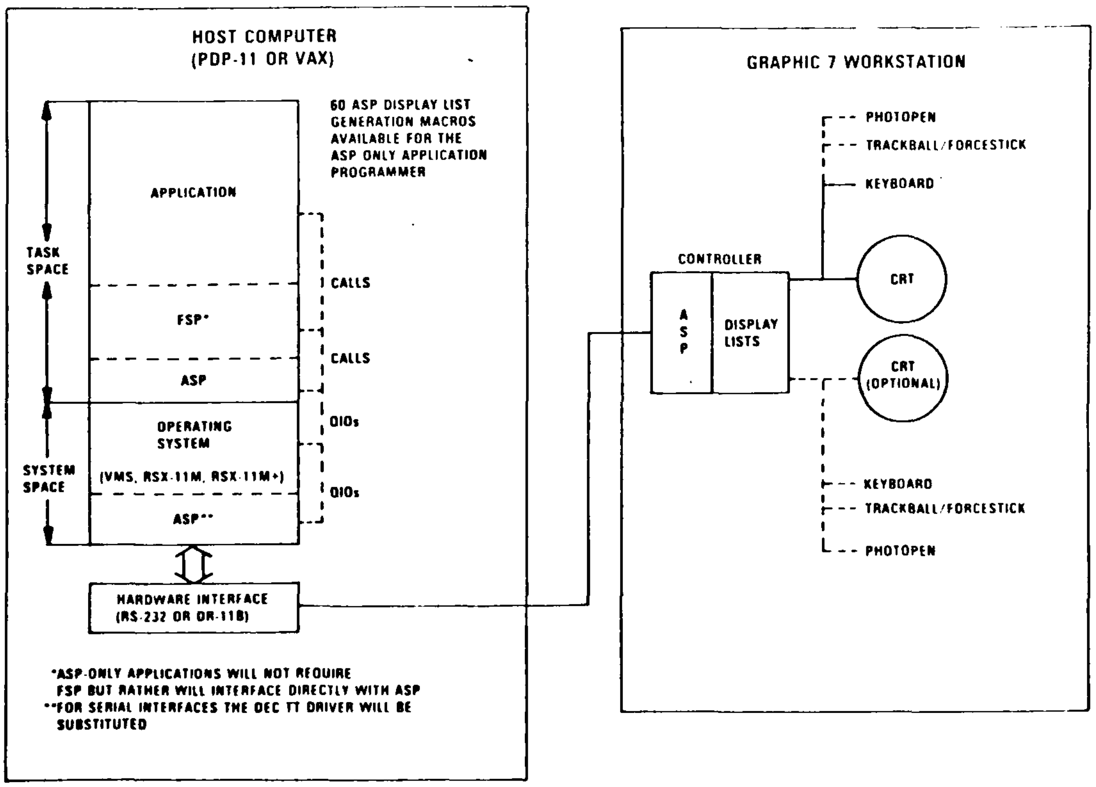
The approximate retail price of a Megatek 7290 graphics processor including one vector display unit, one raster unit, a data tablet/digitizer, alphanumeric keyboard/joystick, a function switch/control dial panel, WAND software, and PROM, user-defined symbols is $80,150.00.

5.2.4 <u>Sanders Associates, Inc.</u>

Sanders Associates manufacturers both vector and raster color display units, but unlike Megatek's single processor/memory buffer system, Sanders controls each of the two types of displays with a specific processor. The vector system will support up to four color display units with input devices, and is expandable up to 128k bytes. The raster system was not investigated, since vector displays are better suited for range safety test monitoring, and since all other units evaluated are vector displays.

The Sanders CRT screen is a 21" (diagonal) screen which has four-color capability. For icon presentation, Sanders has ROM capability for a user-defined set of 32 symbols. The icons may be generated by Sanders, or programmed by a Fortran programmer.

The Sanders software package consists of a set of 69 Fortran or Pascal subroutines which reside in the host computer memory, and a set of 60 Macro assembly language definitions which reside in the work station controller, as well as the host memory (See Figure 5.2.1.). Because the Fortran Support Package (FSP) is device dependent (i.e., a set of subroutines is written for compatibility with the specific host compiler), the memory requirements and throughput inefficiencies usually associated with device independent software packages are significantly reduced. The reduction in memory space, coupled with rapid throughput, provides sufficient room in the host central processing unit for the application program(s) to reside during use.



FSP/ASP DISTRIBUTION

Figure 5.2.1

The assembler support package (ASP) provides graphics programming capability to the assembly language programmer, and distributes part of the graphics processing load into the display unit terminals. The modules in the ASP perform graphic functions such as line drawing, color selection, and character drawing, and host-work station communications such as interrupts from the input devices, initialization of a device, response to a device request, etc..

Sanders produces hardcopy units, light pens, alphanumeric keyboards, trackballs, joysticks, and data tablets. The data tablet size was not specified.

Sanders FACSFAC (undefined in the literature) systems are currently installed at three U.S. locations - Jacksonville, Fla., San Diego, Calif., and Norfolk, Va., - and operate in an air traffic control environment. Specifications for these systems include:

• Area of coverage:	512 x 512 nm
• Targets (tracked objects):	15
• Number of radars:	15
• Number of active display consoles:	16 per site (maximum)
• Geographic maps:	5 per site, 250 vectors and 50 characters per map

Sanders literature indicates their familiarity with the complex components of multiple mission scenarios, even though they do not support that type of operation.

The cost of a Sanders vector graphic display system, including the Terminal Controller, 128k of memory, a ROM symbol set, a 2D Coordinate converter, interconnect panel, one color display monitor, a DEC Fortran and assembly support package, and the necessary connecting cables is approximately $64,000.00

5.2.5 Vector General

Vector General produces at least three graphic display systems, each of which incorporates features and capabilities aimed toward specific markets and applications. The system most closely allied to the other graphic display systems evaluated in this section is the Vector General 3400 Series.

The color display units utilized by all Vector General graphics processors are the 21" diagonal four-color, beam penetration CRT's produced by CPS, a division of Vector General. The 3400 Series, coupled to one host computer, can support up to 24 display units. Vector General accomplishes this by supporting four sets of display control modules, each of which supports up to six CRT monitors, from a single host/graphics processor interface. (See Figure 5.2.2)

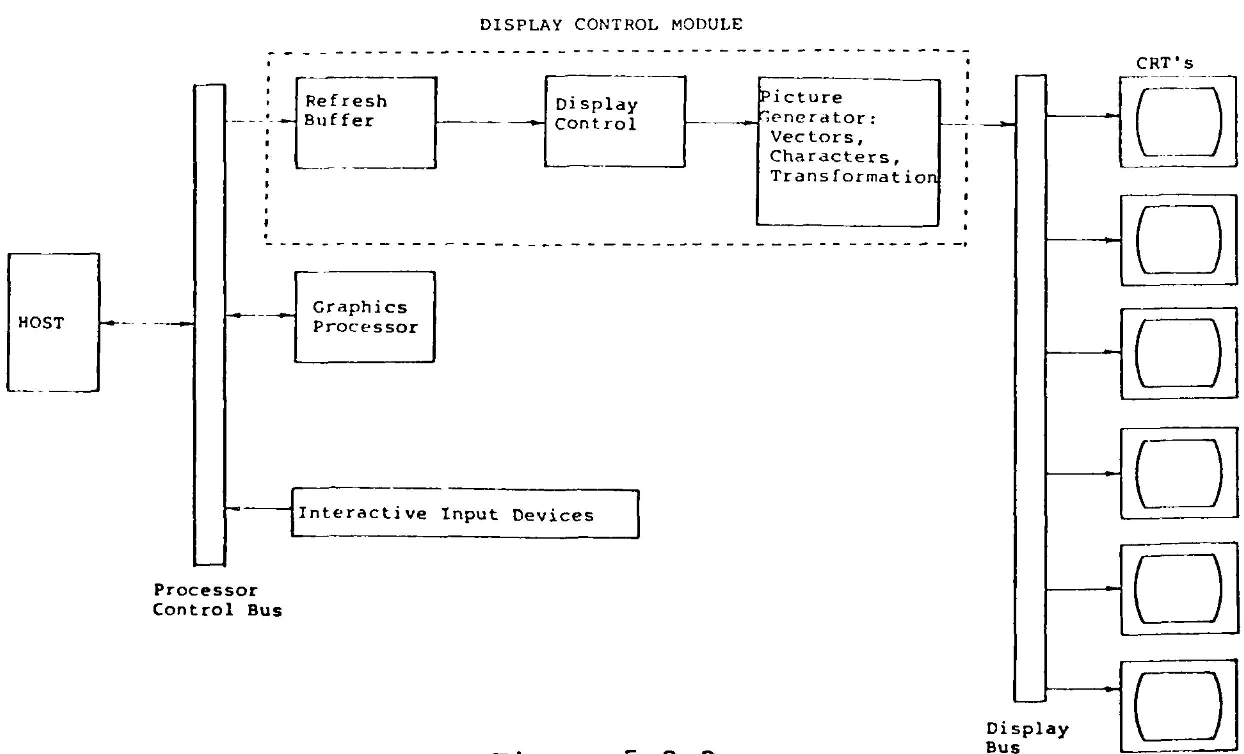


Figure 5.2.2

Other display features include ROM for icon presentation; programmable line texture (dot, dash, etc.), line intensity, and drawing speed; and an internal smoothing technique to generate smooth curves and circles.

The distribution of memory and processing area in the 3400 Series is somewhat different than in the previously discussed display systems. The graphics processor unit has 4k words allocated to the microprogrammed control program; 16 general purpose accumulators; 17 special address registers; a 247 word ROM constant file; and a 248 word RAM data file. In addition, each of the four display control modules contains 64k, 16 bit words (32k bytes) of refresh buffer memory to service the six display units.

The V.G. 3400 Series provides a Fortran callable subroutine package (FGP34) for use in the applications programs. The FGP34 package includes subroutines for handling interactive input devices, addressing the display and device registers, and for activating the micro-programmed set of display instructions which reside in the graphics processor's 4k words control program.

Referring to Figure 5.2.2, the integration of the software and hardware, and the data flow through the system is as follows:

- The applications program containing FGP34 subroutine calls is executing on the host computer, and, based upon a signal from an input device, sends display instructions to the control program.

- The control program converts the instructions (and data) into a buffered display refresh list, and sends the list to the refresh buffer memory.
- The instructions are sent through the display control unit to the appropriate picture generator (vector, character, or picture transformer such as zoom, pan, etc.,) which then sends display data through the display bus to the proper CRT.

The distribution of processing in this manner permits the applications and control programs to function in a dual-processing manner; continuously furnishing display list data to the refresh buffer, which is continously being depleted by the display control unit.

Vector General's input devices consist of an alphanumeric keyboard, light pen, data tablet, joystick, function switches, and control dials.

Retail costs from Vector General were obtained verbally, and not itemized for a complete system, which (for comparative purposes) consists of: a 3400 Series graphics processor, the display control module, one color CRT, an alphanumeric keyboard, a joystick, and a data tablet. The figures quoted for the 3400 graphics processor, display control module, and color CRT amounted to approximately $73,000.00. The inclusion of the peripheral devices, based upon averages of similar devices from other manufacturers, adds about $11,500.00 to that figure.

5.3 Tektronix Color CRT

The Tektronix 4014-1's in current use at the CCF are storage tube display units. Storage tube display units use a CRT screen coated with a special phosphor that contains "on/off" properties. Once the phosphor has been turned on by a high-voltage electron beam, it stays "on" with a low maintaining voltage. The storage tube also contains an electron gun that writes data onto the phosphor screen, and low-voltage activators which keep the phosphors that have been written on "lit". In this way, a picture, such as a background map, is "stored" on the tube screen, as is data which is subsequently added (e.g., the radar target track data).

The Tektronix 4054 option 31 is also a storage tube display; however, it has the capability of presenting refreshed display (the data is repainted 30 times per second) as well as stored data, and may present both types simultaneously. An added enhancement is that refreshed data is presented in an orange color, while storage tube data is presented in green. The Tektronix 4054 option 31 costs approximately $19,140.00.

REFERENCES

1. "Communicating with Computer Graphics: Aviation and Aerospace Gets the Picture," Aviation Week and Space Technology, Nov. 30, 1981

2. "Computer Graphics Display Hardware," Computer Graphics and Applications, Vol. 1, No. 1, (ISSN 0272-1716), January, 1981.

3. Computer Terminals Review, GML Corporation, No. 1, 1981.

4. Southeastern Test and Training Area Plan for Gulf Range Upgrade, SETTA Range Improvement Committee, May, 1981.

5. William F. Lake, Jr., Eglin Real Time Computer Network, (Directorate of Computer Sciences, Computer Systems Design Division, Eglin AFB, Fla.), April, 1980.

6. William F. Lake, Jr., RT Network Implementation Plan, (Directorate of Computer Sciences, Computer Systems Design Division, Eglin AFB, Fla.), 27 October, 1981.

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STATEMENT OF WORK

Currently, the Eglin real-time computer weapon test monitor system available to Range Safety (and other) personnel consists of several black and white, 20 inch screen display units. These units must display a multitude of test information (e.g., destruct lines, weapon trajectories, target trajectories, surface craft in the operating area) vital to the RSO/RDO for making decisions that influence the success of the mission.

The lack of a sufficient variation in color becomes serious as weapons tests evolve to include multiple targets and/or multiple weapons. The problem is further compounded by the small viewing area, which effectively becomes even smaller with the increase in the number of targets and/or weapons.

The contractor is directed to determine the capabilities of large screen display (LSD) units manufactured by several companies with regard to the following items:

1. Compatibility with the current CDC 6600 computer system, as well as the VAX 11/780 computer system, which is proposed for future real time use.
2. Physical size of screen.
3. Screen resolution (density of dot matrix).
4. Multiple color capability
5. Multiple display capability
    a. Split-screen
    b. Simultaneous print/figure

6. Continuous motion capability.

7. Route screen display to hard copy unit capability.

8. Rapidity of response.

9. Variable size display (similar to zoom lens).

10. Light pens or other display controlling instruments.

11. Capabilities of hardware/software packages available for display units.

12. Interface between current hardware/software package control statements and Fortran 5 language.

13. Interface with strip chart recorders.

Based upon the results of the determination, the contractor will recommend candidate display units (maximum of 5 manufacturers) capable of meeting AD real-time range safety requirements.

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